USDA
United States Department of Agriculture
Forest Service
Pacific Northwest Research Station
Research Note PNW-RN-528
September 2000

Managing the Stands of the Future Based on the Lessons of the Past: Estimating Western Timber Species Product Recovery by Using Historical Data

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Abstract

Researchers at the Pacific Northwest Research Station have completed over 100 forest product recovery studies over the past 40 years. Tree, log, and product data from these studies have been entered into a database, which will allow further analysis within, between, and across studies. Opportunities for analysis include stand-to-log-to-final product estimates of volume, quality, and value. Examples of possible database queries include determining the variation in recovery volume and product yield from different age or diameter classes, the relation between percentage of sound log volume and product yield, and the relation between product quality and age.

Keywords: Wood quality, silviculture, modeling, simulation, timber, lumber recovery, veneer recovery.

The best of prophets of the future is the past.
Lord Byron, 1821

Introduction

The Pacific Northwest (PNW) Research Station in Portland, Oregon, has conducted over 100 timber quality recovery studies dating back to the late 1950s for various types of wood products and Western tree species from old growth to plantations. Recovery studies were undertaken to provide forest managers and manufacturers of forest products information to better estimate the volume and value of products from similar trees or logs under similar manufacturing conditions. The Station's mandate also includes conducting research to help forest managers understand the implications of management decisions on the quality and value of the existing and future forest resources as today's management decisions influence various products that will be available in the future.

An effort was begun in 1998 to test the feasibility of aggregating and synthesizing wood product recovery data across previous studies. Historically, individual recovery studies were undertaken to meet immediate objectives, for example, to develop log and tree grades in support of Forest Service timber sale appraisals or to relate forest management practices to wood characteristics. Emphasis was primarily on the log-to-product stage of recovery. Although tree data were collected, little analysis was undertaken to link tree-stand condition to product recovery. Also, until now, only limited attempts have been made to analyze the data across studies to draw broader inferences (exceptions include Willits and Fahey [1988] and Fahey and others [1986]).

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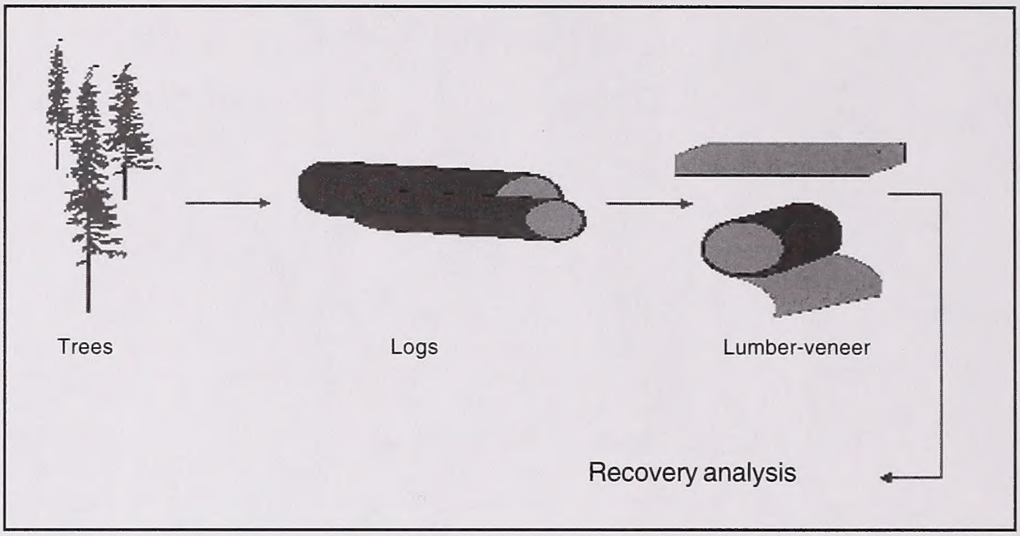

Figure 1—Data and analysis for recovery studies.

The objective of this effort is to provide an understanding of the characteristics and value of Western tree species in forest management history and manufacturing strategy and technology based on these aggregated recovery data sets, with special emphasis on tree-level data. Tree-level data can be aggregated to simulate many different stands under various treatment regimes. Current research questions are less likely to be directed at the log or even stand level and more likely to be addressed at some broader spatial scale. The information in this database could allow product recovery modeling at the watershed level.

Methods

Figure 1 is a conceptual model of previous studies. Trees often were selected to cover the range of sizes and characteristics existing in a geographic area at the time and were not representative of the natural frequencies of occurrence of tree size for that area. Trees were measured and harvested, and then the logs were graded and scaled at woods and mill lengths and then manufactured into products that were in turn measured and graded.[2] Data were analyzed and summarized at the study level.

In this synthesis project, all the trees from multiple studies or individual trees across studies can be combined along subregional lines, by tree age, manufacturing method, time periods, or some other user-determined grouping (fig. 2). Stand-level recovery can then be simulated based on an aggregation of trees. Studies even of the same species differed considerably in many characteristics; for example, geographic range, mill type, and stand age. To effectively deal with these differences, it is necessary to recognize them and aggregate where the differences are minimized and the aggregation can be statistically justified. The statistical approach to this[3] is to test combined data to determine whether those characteristics associated with a particular study (for example,

[2] Parry, D.; Lowell, E.; Stevens, J.A. [and others]. Guide to conducting forest product recovery studies at the Pacific Northwest Research Station. Manuscript in preparation.

[3] Stevens, J.A.; Barbour, R.J. Estimating western hemlock lumber recovery and quality from historical data. Manuscript in preparation.

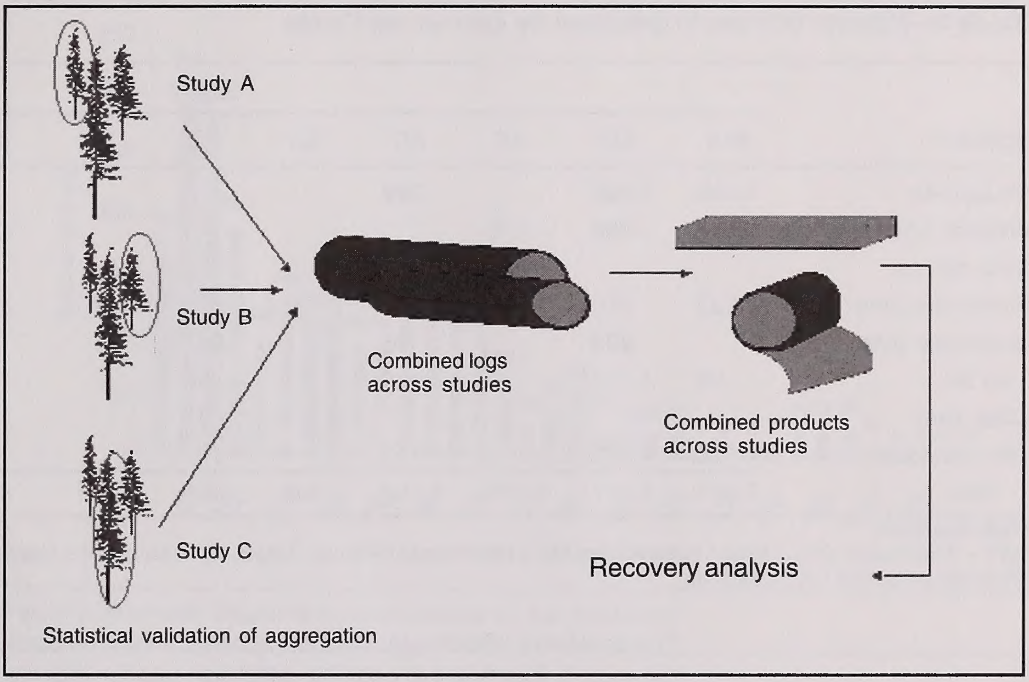

Figure 2—Simulation of stands through study aggregation.

different manufacturing equipment, characteristics of logs, and skill of sawyer) constitute a significant explanatory variable for recovery when combined with similar studies. Only trees from studies that show no significant difference are combined.

We expect this modeling system to be robust over a wide range of conditions because it can reduce the variation inherent in volume recovery and grade yield equations that arise from trees as their size and age change. For example, information in this database can account for the fact that a different mix of lumber grades can be manufactured from 300-year-old, 35-inch trees than can be manufactured from 80-year-old, 35-inch trees. It also can account for the difference in lumber widths that can be manufactured from 80-year-old, 15-inch trees as compared to 80-year-old, 25-inch trees. With such an extensive data set, we have a unique ability to select trees for developing customized regression models that more closely match the sample trees in our analysis and to choose manufacturing strategies that match those of our simulation scenarios.

The database includes data from over 100 studies from across the Western States covering all the major timber species (table 1). Not all the tree, log, and lumber data from every study is available in digital form that can be included in the database, but the trees included in the database cover the range of the most frequently found sizes and ages. The number of trees by state for data covering the most commonly measured tree characteristics (height and diameter at breast height [d.b.h.]), log measures (small-end diameter, length, and volume), and lumber measurements (length, width, thickness, grade, and volume) are shown in table 1.

Table 1—Number of trees in database by species and state

	State[b]										
Species[a]	WA	OR	AK	MT	SD	ID	CO	AZ	WY	CA	Total
Douglas-fir	1,790	2,692		399						439	5,320
Western hemlock	554	268	875								1,697
Sitka spruce			552								552
Ponderosa pine	222	870		262	400	229	341	414		476	3,214
Lodgepole pine		223		86		219			378		906
True firs	98	1,393		116		48				716	2,371
Other pine						201				325	526
Other species	280	401		703		171				171	1,726
Total	2,944	5,847	1,427	1,566	400	868	341	414	378	2,053	16,312

[a] See footnote 4.
[b] WA = Washington, OR = Oregon, AK = Alaska, MT = Montana, SD = South Dakota, ID = Idaho, CO = Colorado, AZ = Arizona, WY = Wyoming, and CA = California.

The database allows user-defined queries within the constraints of the parameters measured. Examples of possible database queries include determining:

- The variation in recovery volume and product yield from different age-diameter classes
- The relations between percentage of sound log volume and product yield
- The relations between product quality and age

To illustrate the type of data available, figure 3 shows the number of west-side Douglas-fir[4] trees in the database by 20-year tree age class. Figure 4 shows the distribution of the true fir trees in the database by 2-inch diameter class. Figure 5 shows the 5-inch diameter class distribution for the ponderosa pine trees in the database. Table 1 and the following figures give a sense of the analytical possibilities of the database when combined with measures of product recovery.

[4] Common and scientific names and authorities for tree species are shown in table 2.

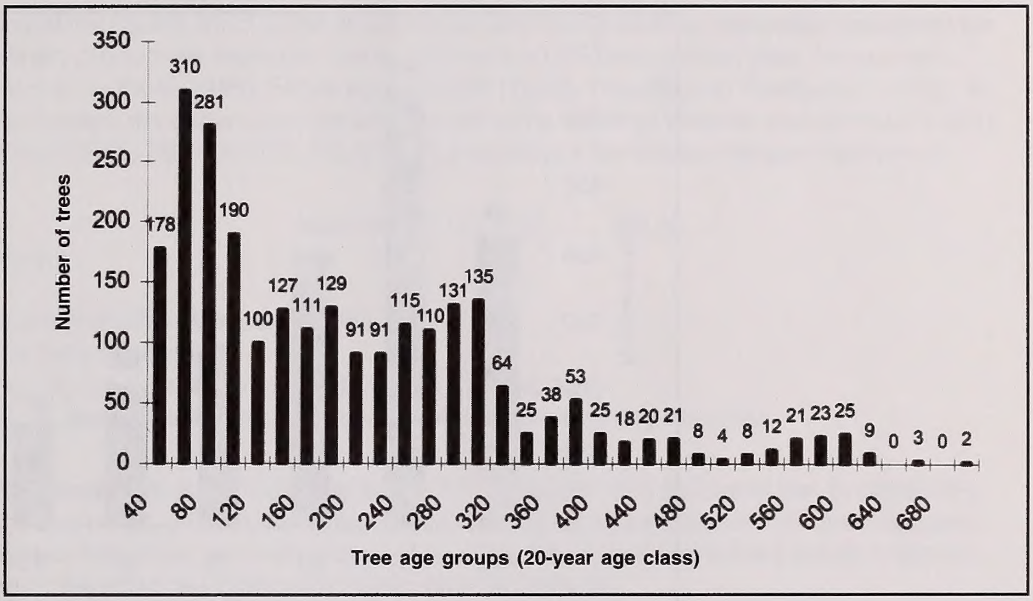

Figure 3—West-side Douglas-fir trees in database by age distribution.

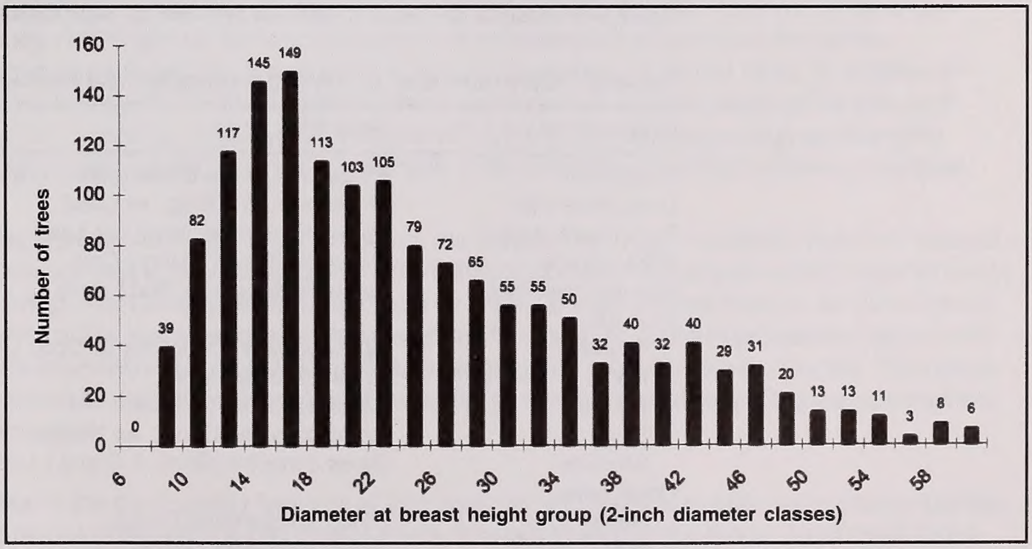

Figure 4—True fir trees in database by 2-inch diameter distribution.

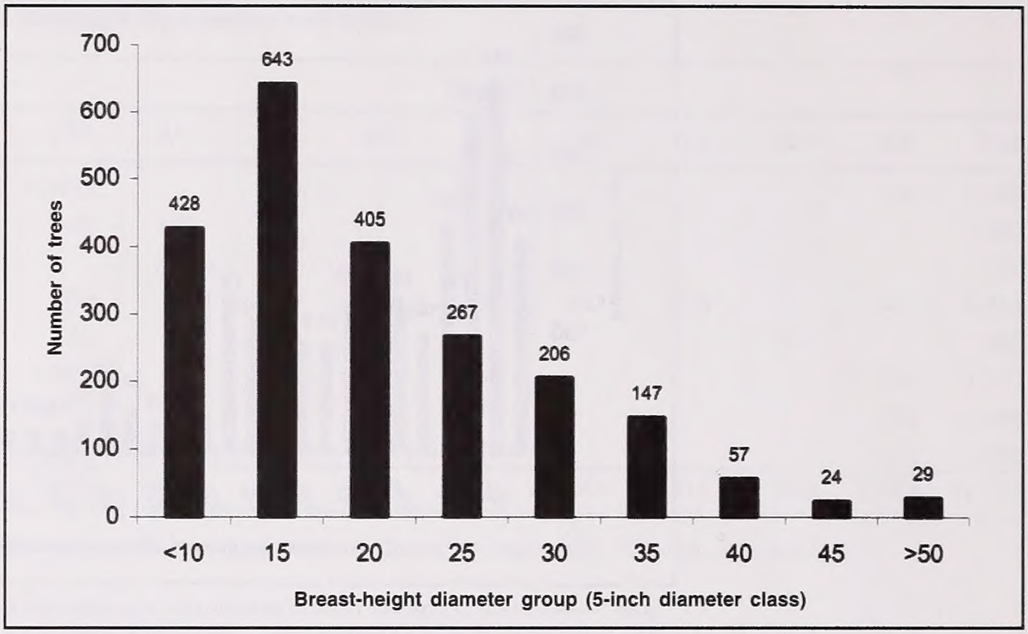

Figure 5—Ponderosa pine trees in database by 5-inch diameter distribution.

Table 2—Common and scientific names of tree species in the database

Common name	Scientific name
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
Lodgepole pine	*Pinus contorta* Dougl. ex Loud.
Ponderosa pine	*Pinus ponderosa* Dougl. ex Laws.
Sitka spruce	*Picea sitchensis* (Bong.) Carr.
Western hemlock	*Tsuga heterophylla* (Raf.) Sarg.
True firs:	
Grand fir	*Abies grandis* (Dougl. ex D. Don) Lindl.
Noble fir	*Abies procera* Rehd.
Red fir	*Abies magnifica* A. Murr.
Silver fir	*Abies amabilis* Dougl. ex Forbes
White fir	*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.
Other pine:	
Sugar pine	*Pinus lambertiana* Dougl.
White pine	*Pinus monticola* Dougl.
Other species:	
Black oak	*Quercus velutina* Lam.
Incense-cedar	*Libocedrus decurrens* Torr.
Red alder	*Alnus rubra* Bong.
Western larch	*Larix occidentalis* Nutt.
Western redcedar	*Thuja plicata* Donn ex D. Don

Recovery Calculations

One of the objectives of all the recovery studies was to develop regression equations for primary product (for example, lumber and veneer) volume recovery (see, for example, Ernst and others [1986], Fahey and Woodfin [1982], Woodfin and Snellgrove [1976]). In most cases, the explanatory variables were some variation of small-end diameter (SED) of logs (SED, SED^2, 1/SED, $1/SED^2$). The equations have taken the general form of,

$$\text{recovery} = C + B_1X_1 + \ldots + B_nX_n,$$

where

recovery is CR%, LRF, or BF/CF LUM;[5]
C is the y intercept;
$X_1 \ldots X_n$ is a 1 x n array of explanatory variables; and
$B_1 \ldots B_n$ are the coefficients associated with the explanatory variables.

Goodness of fit as measured by the r^2 of the equation was generally low. In comparing across studies, other independent variables describing log characteristics will be used (for example, taper and percentage of sound volume), and preliminary analysis shows the r^2 values to be significantly higher (see footnote 3).

Applying the equations developed through the above procedure and testing for cross-study validity allows the land manager to predict product recovery under various management regimes for an existing or projected stand of similar trees. In addition to recovery equations, the database allows estimation of specific products by size and grade. Users can supplement the data with their local knowledge such as changing technology where they have an estimate of the increase in product recovery over time.

Discussion

Regardless of the aggregation method, the objective is to use multistudy empirical product recovery data to describe possible alternative outcomes from various local or regional forest management strategies. Strategies will be linked to local actions that can be described in terms of the characteristics of trees removed from stands during management treatments. This information will provide input data for aggregated product recovery models. The output from these models will form part of the basis for economic analyses of the various regional strategies.

One of the most useful features of this analysis is to be able to take the recovery studies to the beginning of the production chain, that is, to trees at the forest stand level. Traditionally, forest managers (particularly those who are not part of a vertically integrated company supplying their own mills with raw materials) do not include recovery of products in their management projections. The aggregated recovery database allows this to be a part of the management decisionmaking process.

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[5] CR% (cubic recovery percentage) = lumber CF/log CF (100), LRF (lumber recovery factor) = lumber BF/log CF, and BF/CF LUM (board-feet to cubic-feet lumber) = lumber BF/lumber CF.

Policymakers also can profit from the type of analysis described here. Projection of future stand conditions based on current management regimes implies that certain products will be available in the future. These types of analyses are crucial in determining which industries a region will be able to support. Conversely, estimates of future demand could lead to projections of the kinds of trees or stands that will be necessary to provide these products.

The database also contains much information about the types of products and their relative quality that can be manufactured from older, larger trees. These types of trees are rarely available in today's resource. Many ecologically based management scenarios include the eventual harvest of small numbers of large trees that some managers expect to have extraordinary commercial value. Analysis of the information embodied in the tree-quality database will help to quantify their value. These types of case-by-case analyses will assist both resource managers and policymakers in evaluating and understanding the likely outcomes of proposed management actions.

Future Research

This database of wood product recovery studies has been developed and refined so that analysis can include western hemlock, Douglas-fir, true firs, ponderosa pine, lodgepole pine, and other western timber species. The PNW Research Station will use the data in efforts to expand analyses from the tree level to the stand to the watershed level, from single species to mixed stands and other relevant combinations. The first attempt to scale up to tree level data can be found in Stevens and Barbour (in prep., see footnote 3).

The capability to link recovery data with other analytical tools, regional studies, and databases will allow much richer opportunities for analyses covering large land areas. Some of the possibilities include:

- Quality-based analysis of timber produced jointly with other forest products and amenity values
- Links with small-diameter utilization studies
- Ability to use inventory databases like the Forest Inventory and Analysis west-wide database to expand to multistate levels
- Links with individual tree growth and yield models such as ORGANON (Hann and others 1997) and the forest vegetation simulator (Teck and others 1996) to integrate a wood-quality component to growth projections
- Cell-based (quasi-geographic at the timbershed level) links to current and projected processing facilities
- Increased understanding of the economic implications of silvicultural decisions through better understanding of wood quality outcomes

As to the feasibility and value of aggregating across studies, preliminary analysis (see footnote 3) shows that such aggregation, when undertaken with caution, can generate useful results with acceptable statistical validity.

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